



The NOvA Experiment

WIN'05
Delphi
8 June 2005

Gary Feldman



The NOvA Experiment

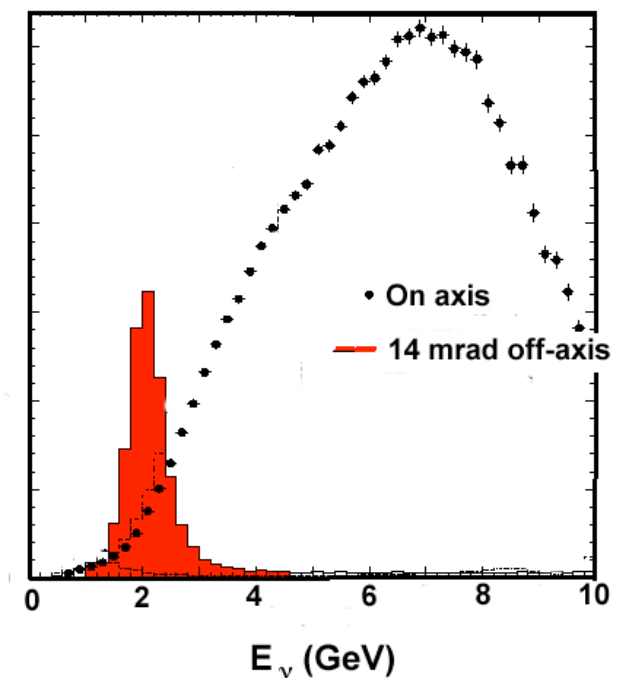
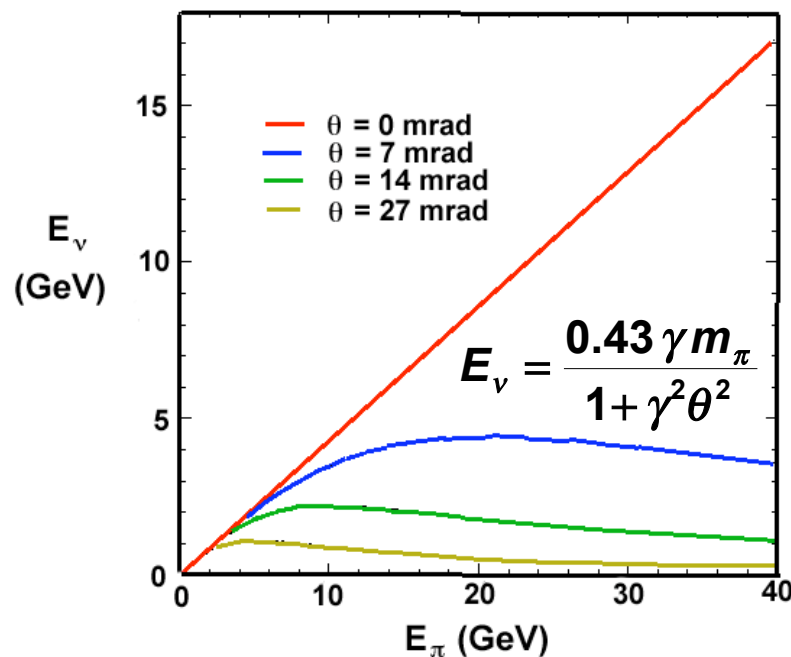
(NuMI Off-Axis ν_e Appearance Experiment)

- NOvA is an approved Fermilab experiment optimized for measuring ν_e appearance with the goal of improving MINOS's $\nu_\mu \rightarrow \nu_e$ measurement by approximately an order of magnitude.
- The NOvA far detector will be
 - a 30 kT “totally active” liquid scintillator detector
 - located 15 mrad (12 km) off the NuMI beamline axis near Ash River, MN, 810 km from Fermilab
- The uniqueness of NOvA is the long baseline, which is necessary for determining the mass ordering of the neutrino states.



Off-Axis Rationale

- Both Phase 2 experiments, NOvA and T2K are sited off the neutrino beam axis. This yields a narrow band beam:
 - More flux and less background (ν_e 's from K decay and higher-energy NC events)





NOvA Far Detector

“Totally Active”

30 kT:

24 kT liquid scintillator

6 kT PVC

32 cells/extrusion

12 extrusions/plane

1984 planes

Cell dimensions:

3.9 cm x 6 cm x 15.7m

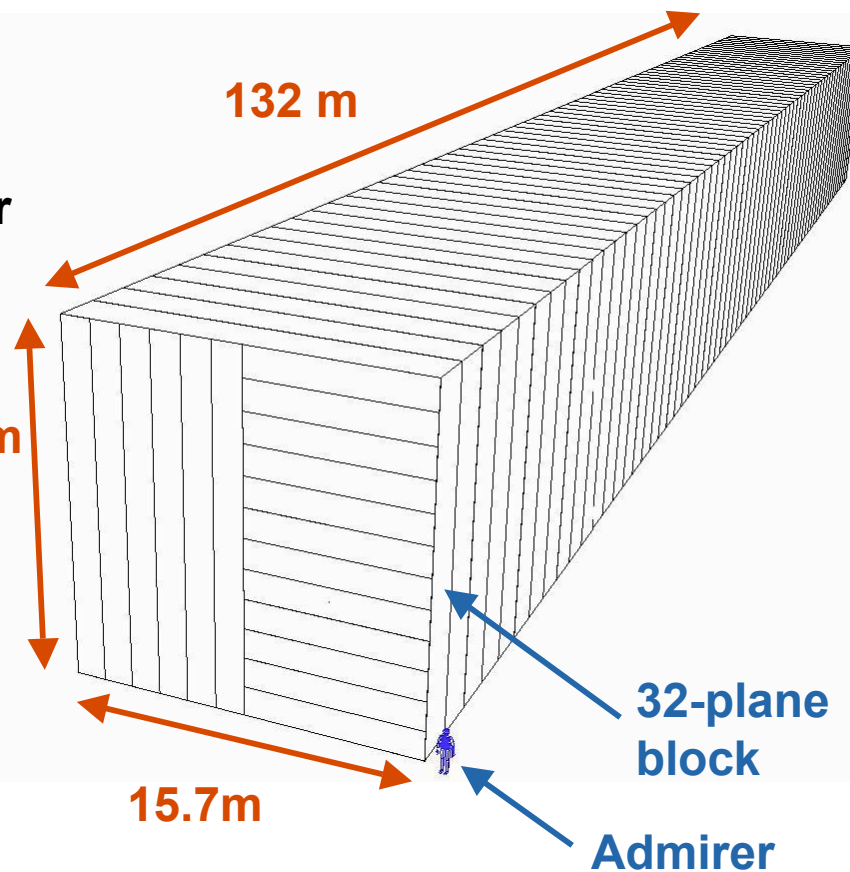
(0.15 X_0 thickness)

Extrusion walls:

3 mm outer

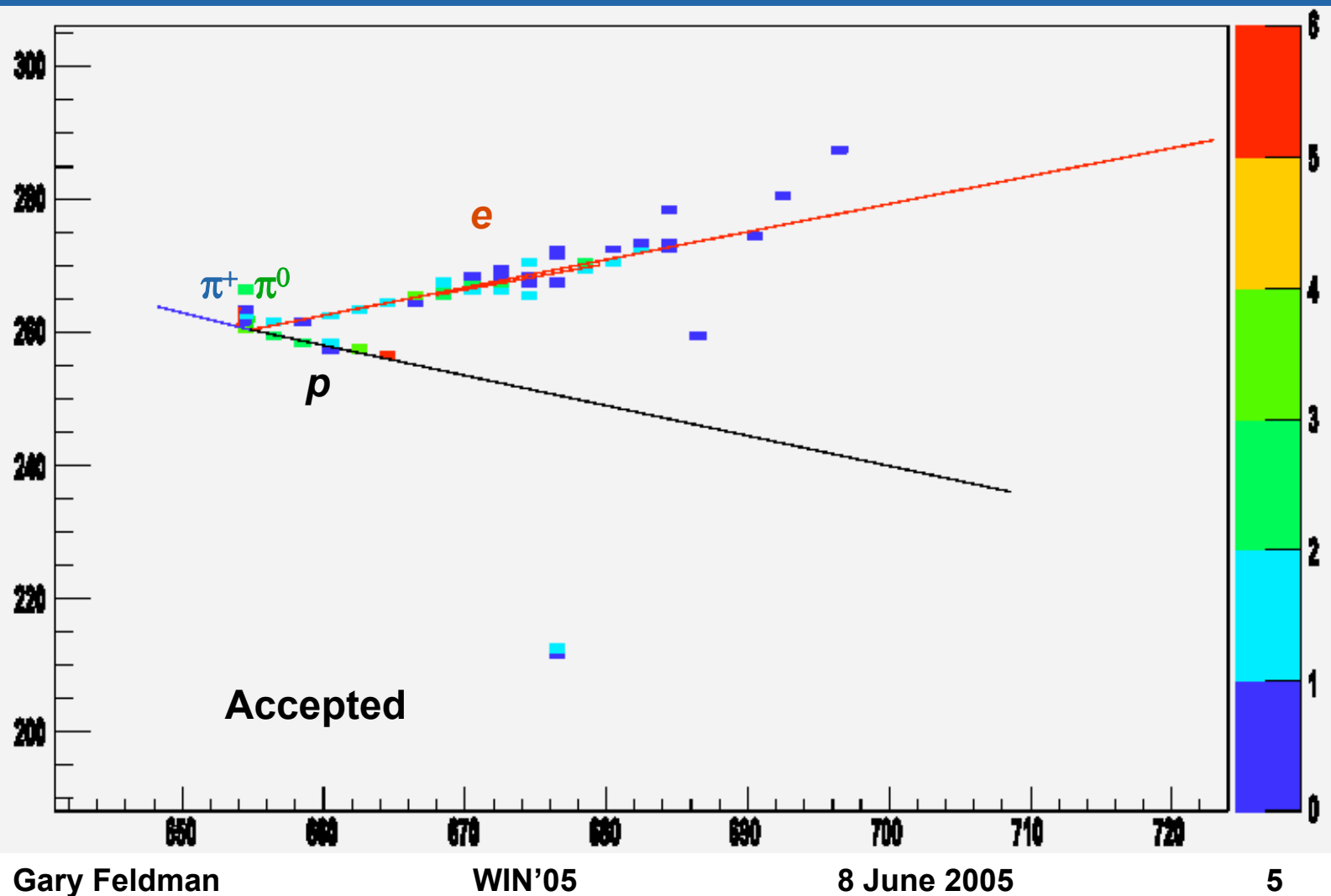
2 mm inner

**U-shaped 0.8 mm WLS
fiber into APD**



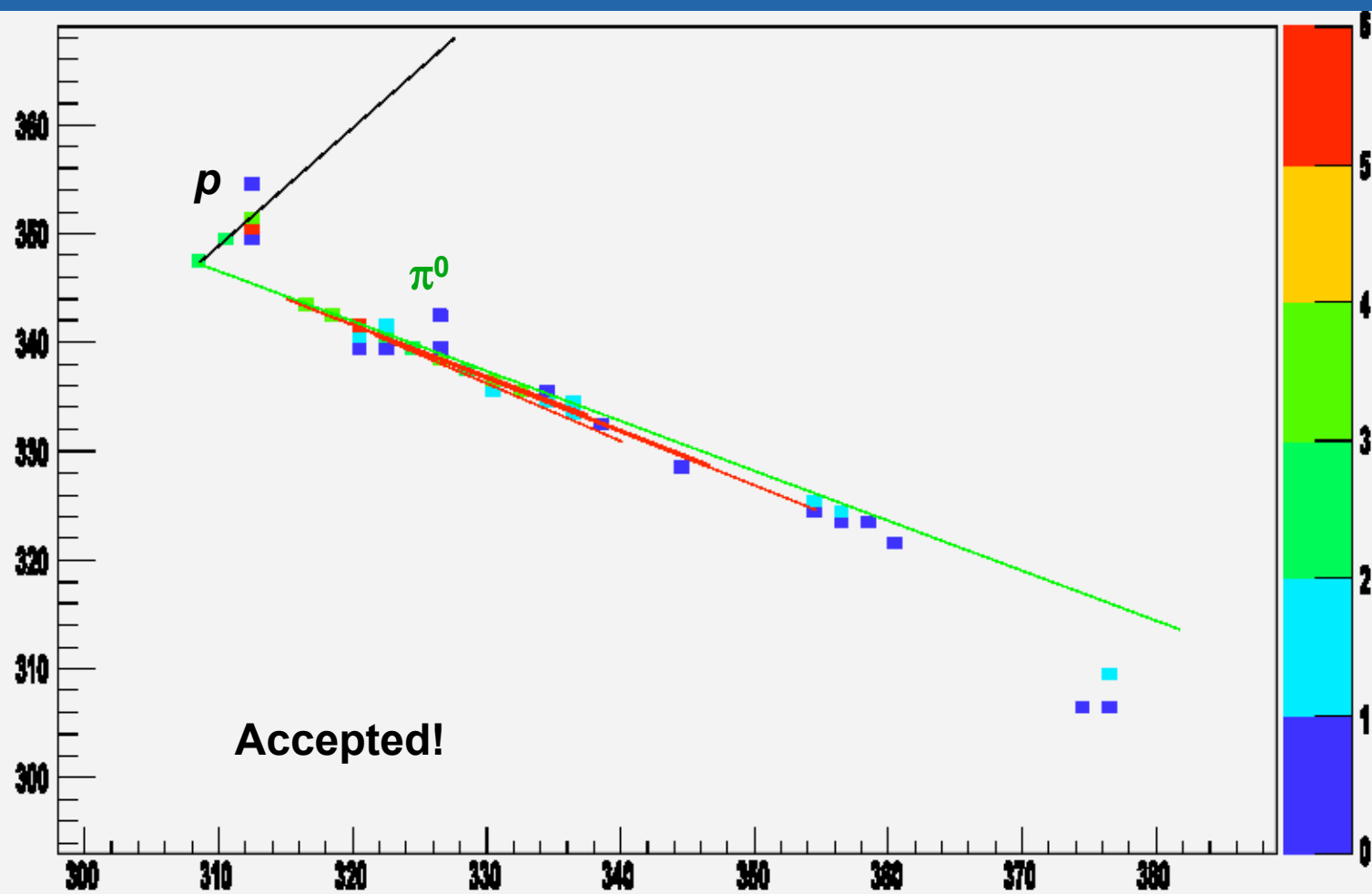


1.87 GeV $\nu_e N \rightarrow e p \pi^+ \pi^0$ x-z View



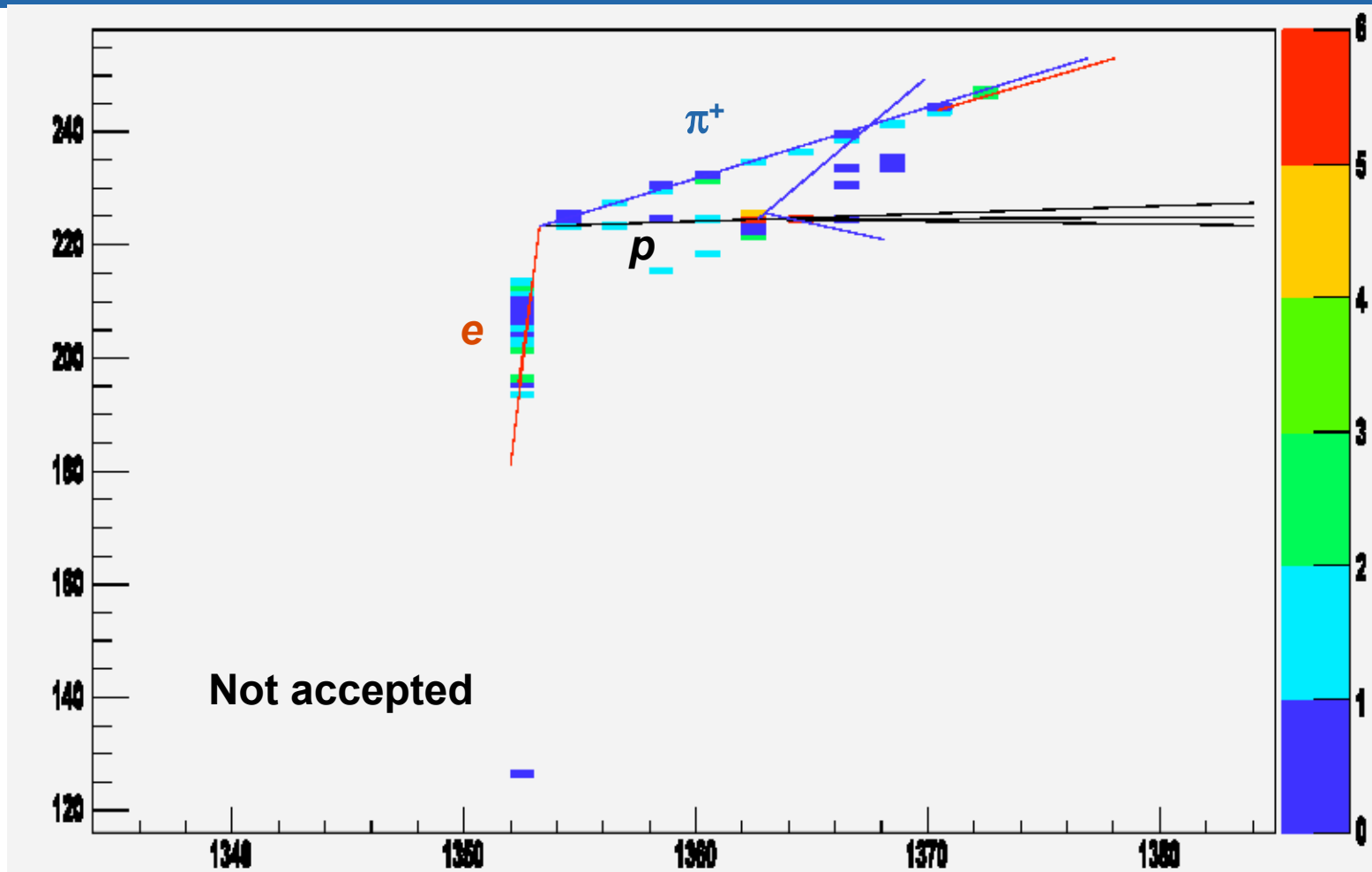


2.11 GeV $\nu_\mu N \rightarrow \nu_\mu p \pi^0$ x-z View



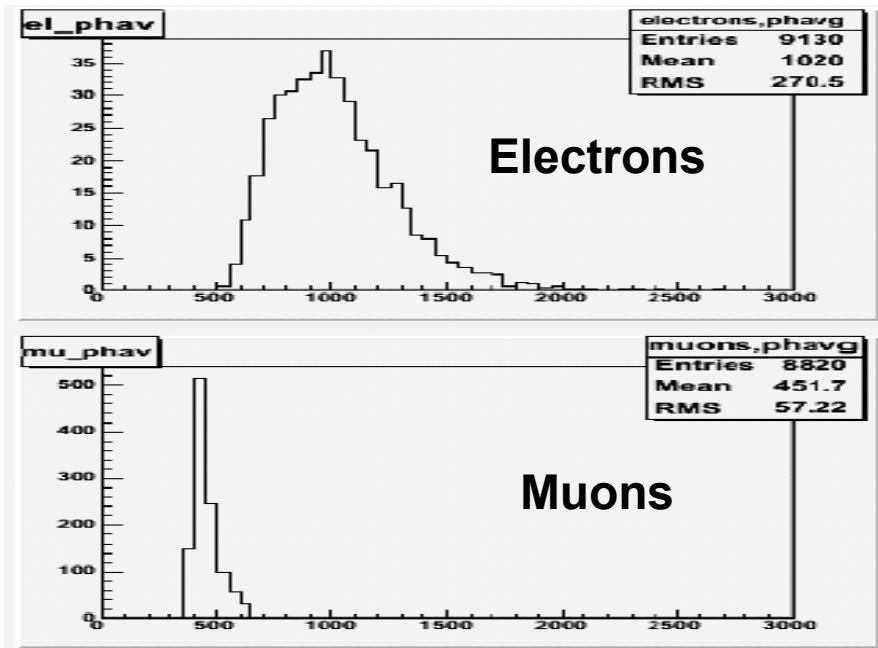


1.86 GeV $\nu_e N \rightarrow e p \pi^+$ x-z View

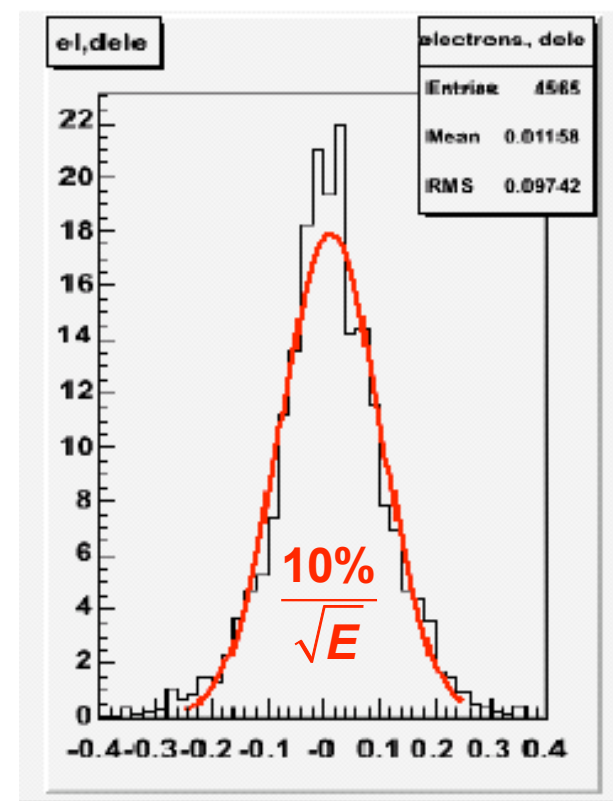




Electron ID and Resolution



Average pulse height per plane



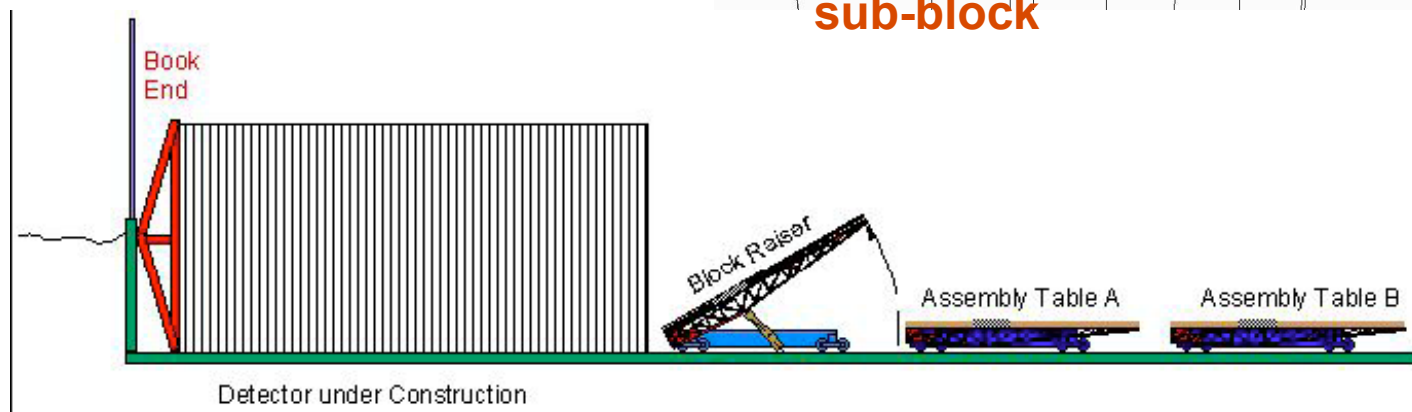
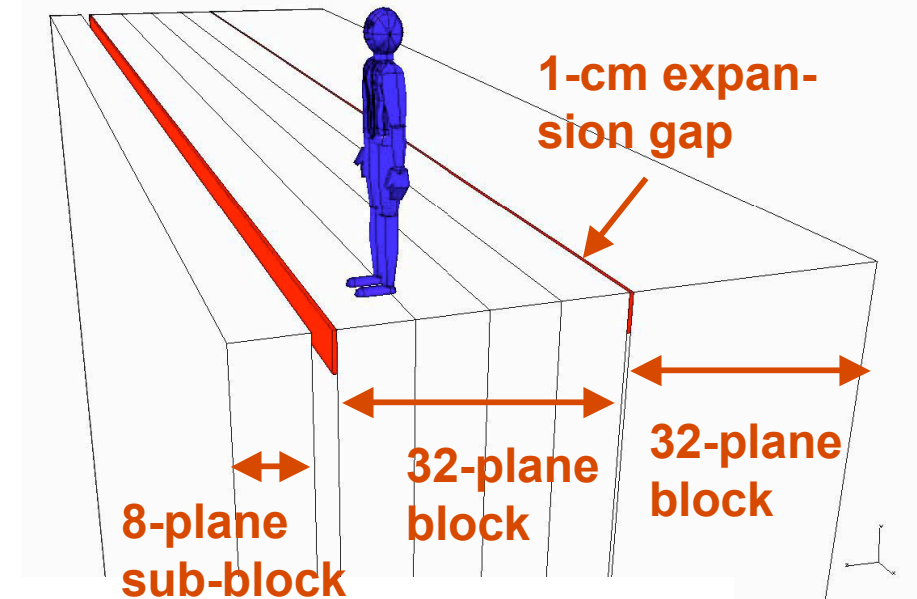
Electron resolution



Far Detector Assembly

One 8-plane sub-block assembled per day

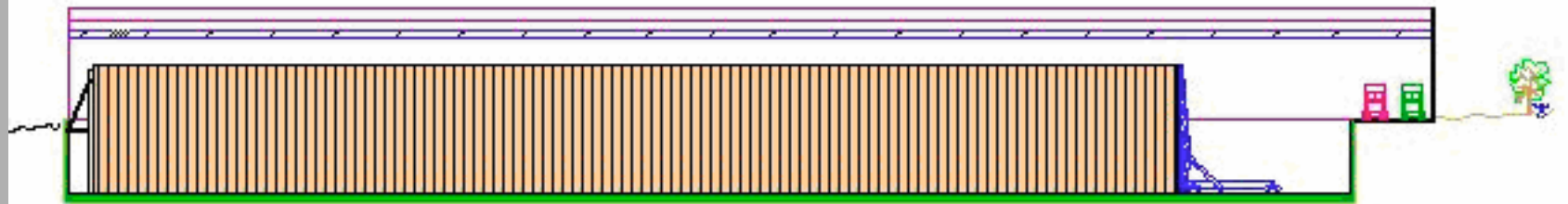
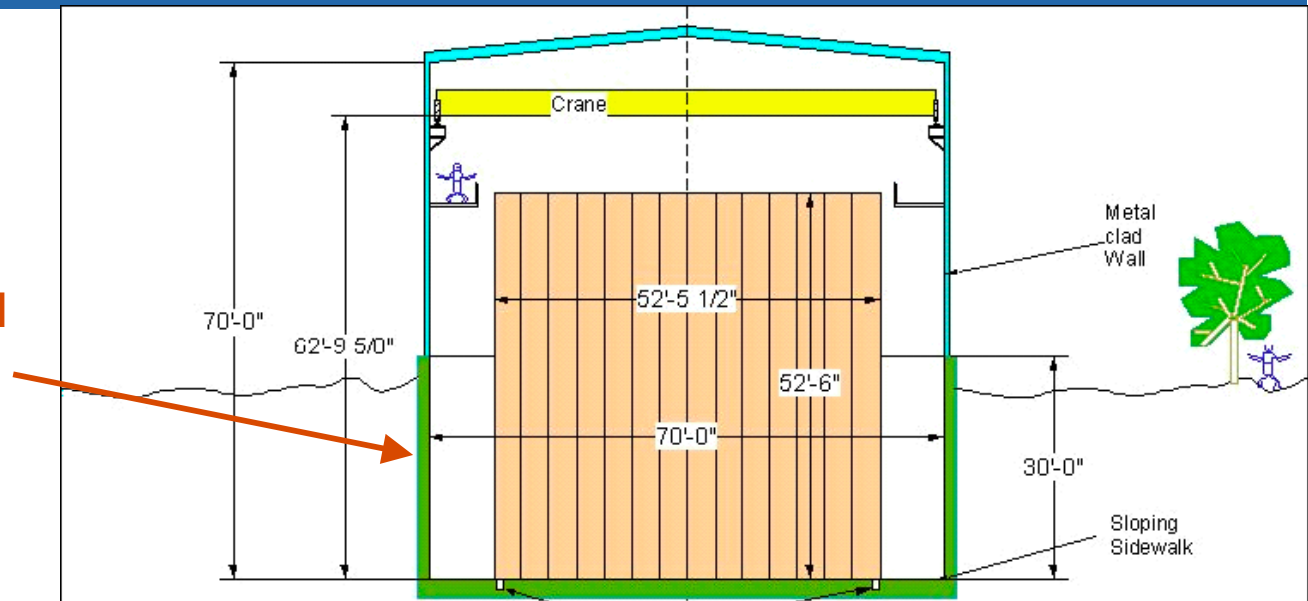
Detector has 248 sub-blocks





Far Detector Building Proposal Design

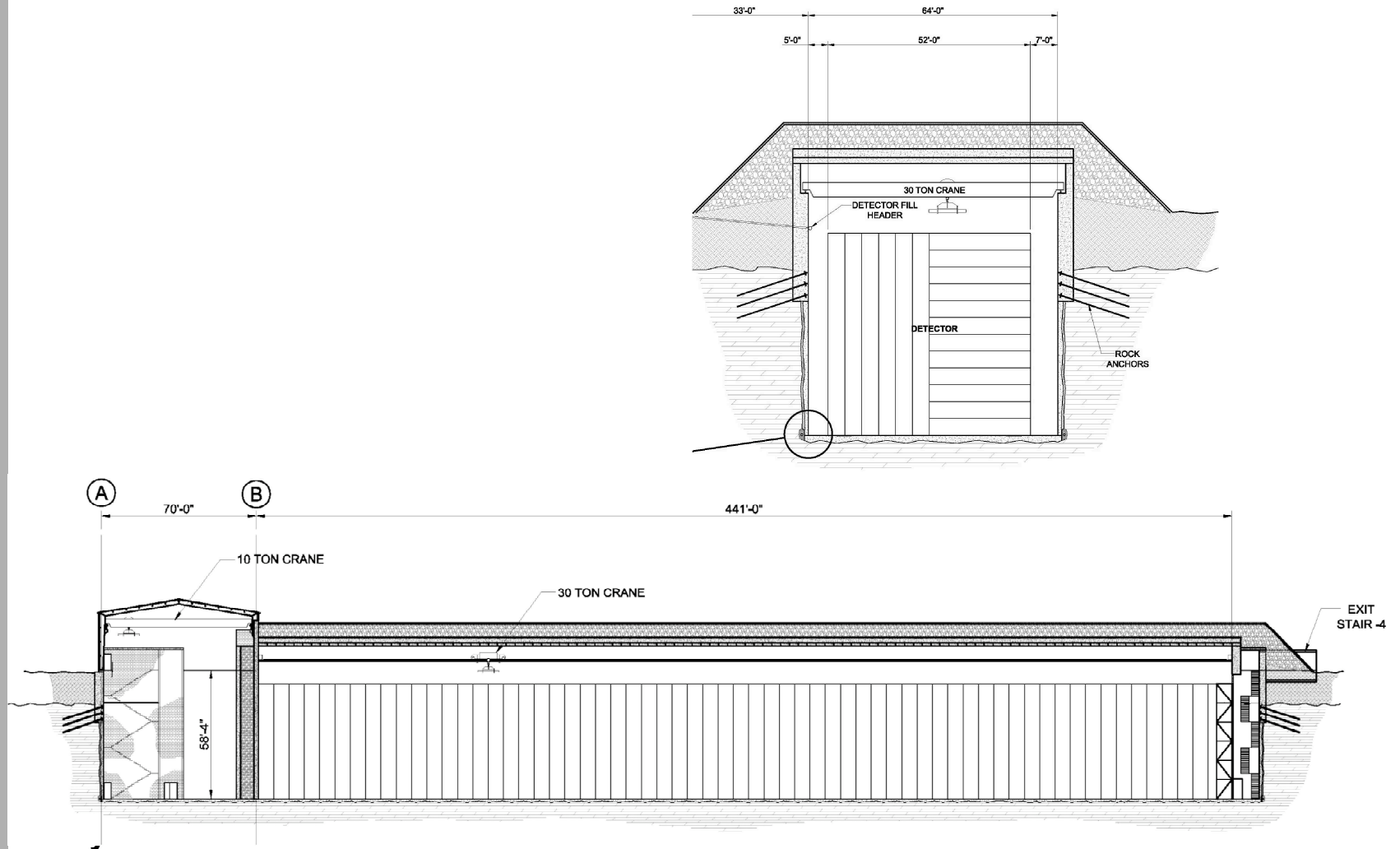
**Bathtub for full
containment**





Far Detector Building

Design with Overburden





Near Detector

8-plane block
10.6 T full
1.6 T empty

9.6 m

262 T
145 T totally active
20.4 T fiducial
(central 2.5 x 3.25 m)

5 m



3.5 m

Muon catcher
1 m iron

Shower containment region

Target region

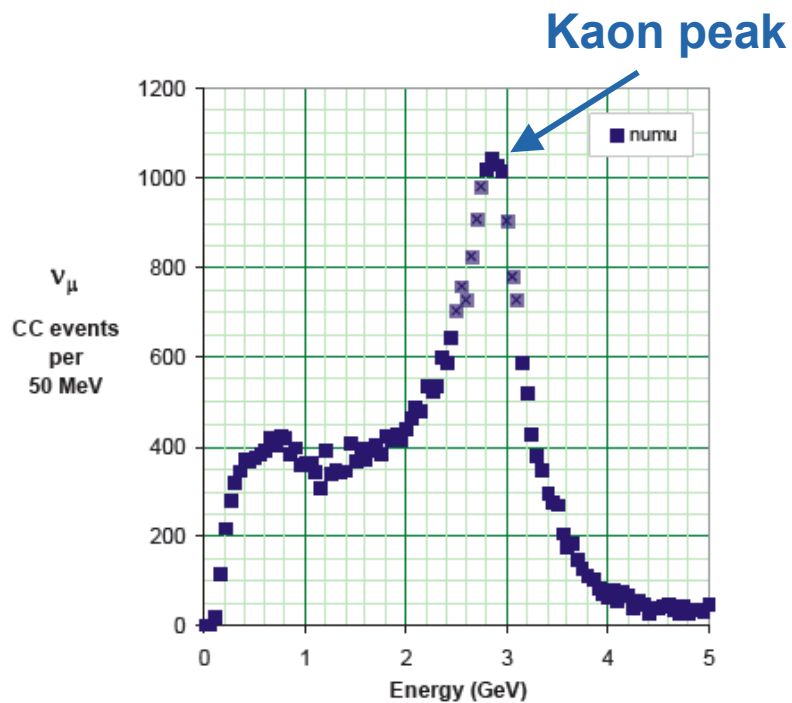
Veto region



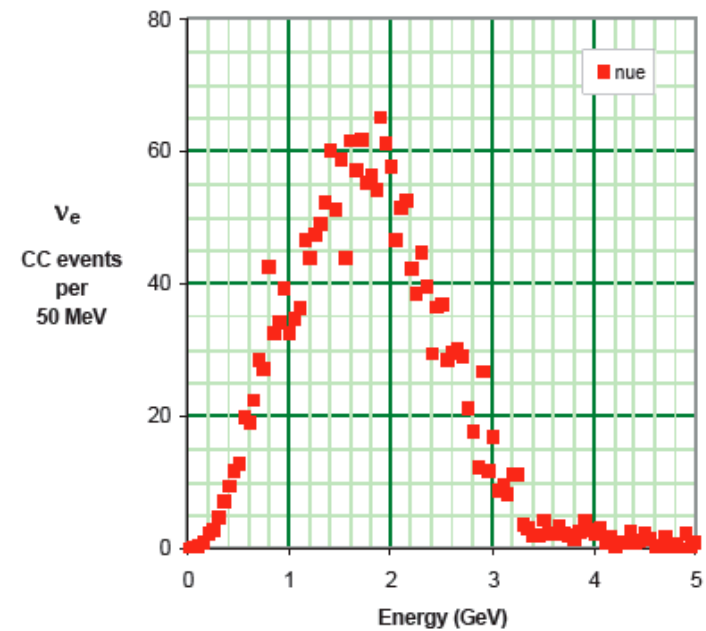


Near Detector in MINOS Surface Building

6.5×10^{20} pot in 75 mrad off-axis beam



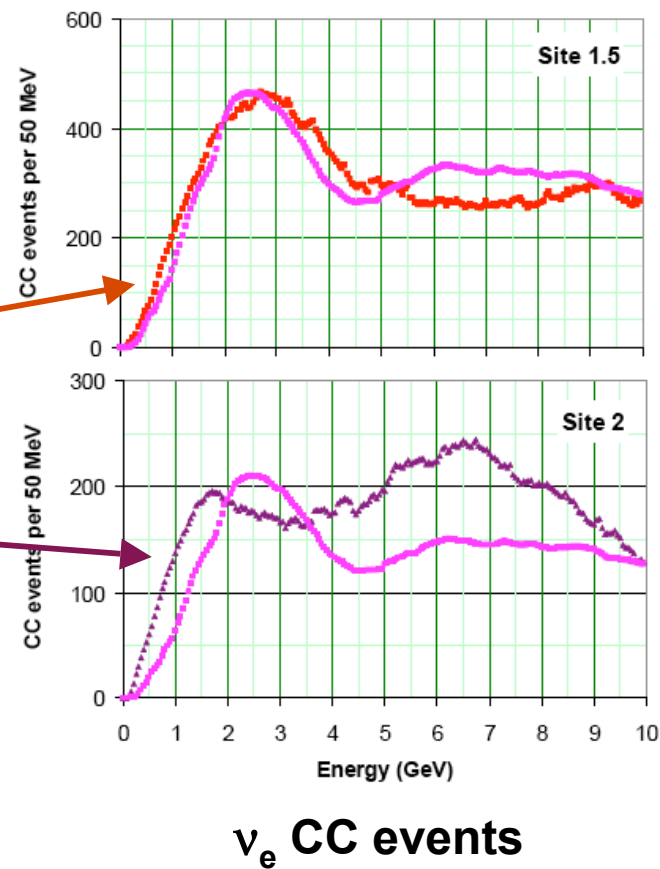
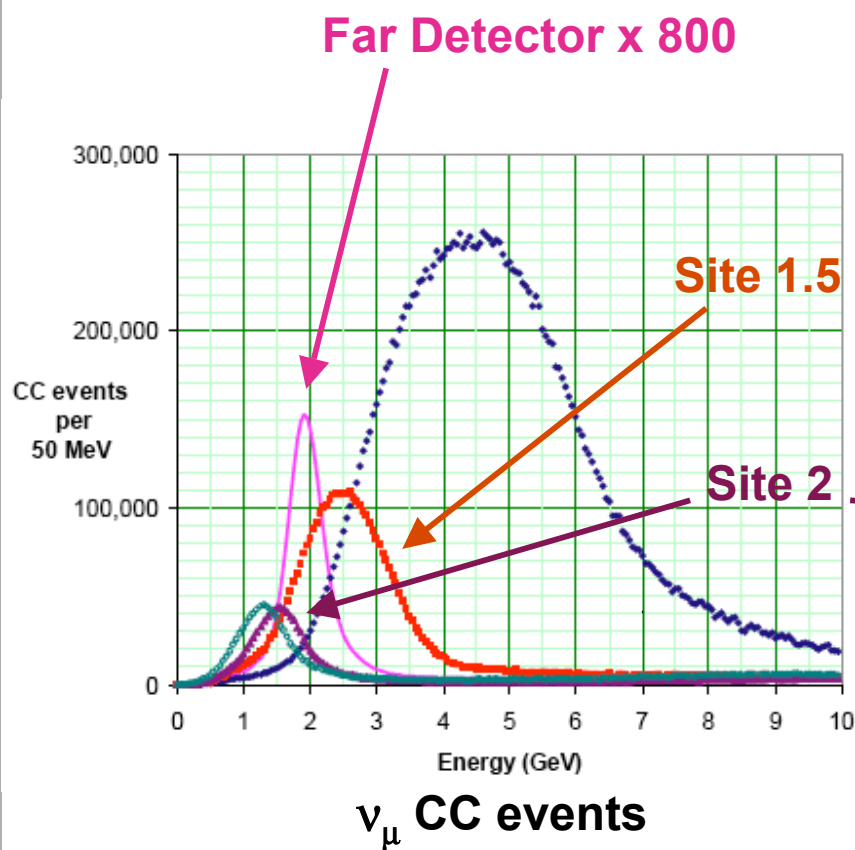
45,000 ν_μ CC events



2,200 ν_e CC events



Near Detector in the Access Tunnel





Change in NOvA Prospects

- **The cancellation of the BTeV experiment caused a major change in the prospects for NOvA**
 - Funds are available for medium size new initiatives
 - More protons are available
- **DoE has signaled that it will prepare to put funds for NOvA in the FY07 budget**
 - Pending NuSAG/P5 and OMB approval
- **Strong Fermilab support**
 - Only approved experiment in the post 2010 era

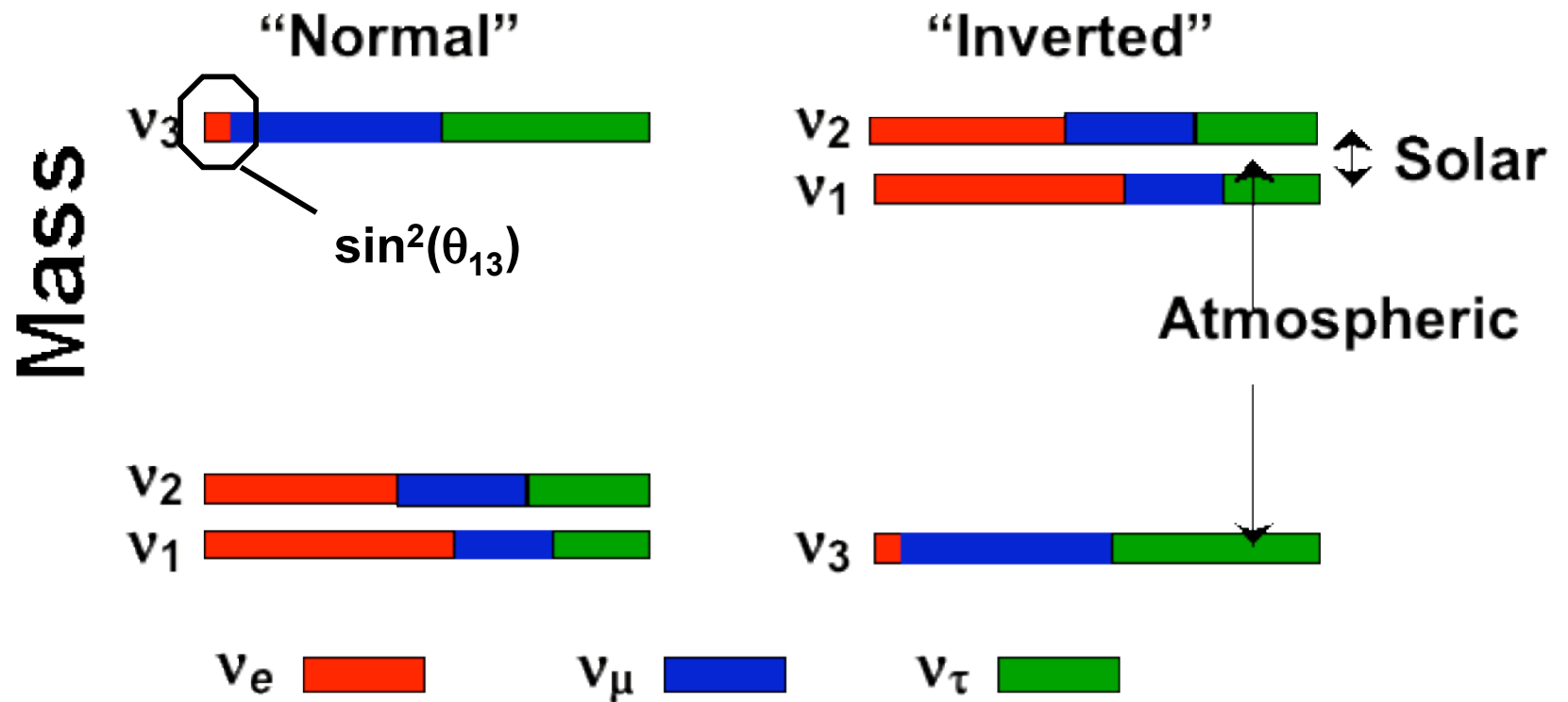


Post-Collider Proton Plan

- **Proton Plan with Collider**
 - 9/11 Slip-stacked Booster batches at 5.5×10^{12} p/batch
 - Repetition rate = 0.8 s (Booster) + 1.4 s (Ramp) = 2.2 s
 - 10% for Collider shot setup + 5% for antiproton transfer
 - $\Rightarrow 3.4 \times 10^{20}$ protons/yr
- **Post-Collider Proton Plan**
 - 11 batches for neutrinos $\Rightarrow 11/9 = 1.22$ factor
 - Hide Booster filling time in Recycler $\Rightarrow 0.8$ s $\rightarrow 0.067$ s
 $\Rightarrow 2.2$ s $\rightarrow 1.467$ s = 1.50 factor
 - Save 10% shot setup and 5% antiproton transfer = 1.17 factor
 - $\Rightarrow (3.4 \times 10^{20} \text{ protons/yr})(1.22)(1.50)(1.17) = (7.3 \times 10^{20} \text{ protons/yr})$
- Negotiated rate is 90% of this: $(6.5 \times 10^{20} \text{ protons/yr})$
- Proton Driver rate taken as 25×10^{20} protons/yr

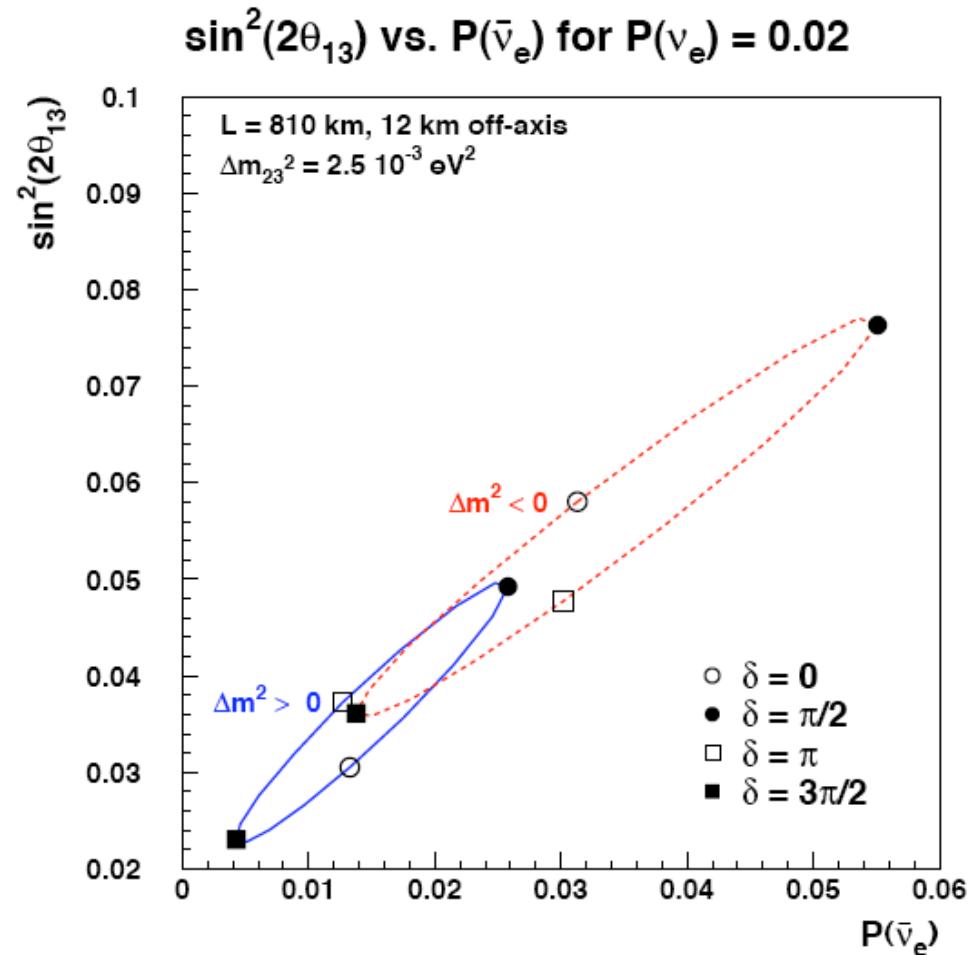


What Do We Know?





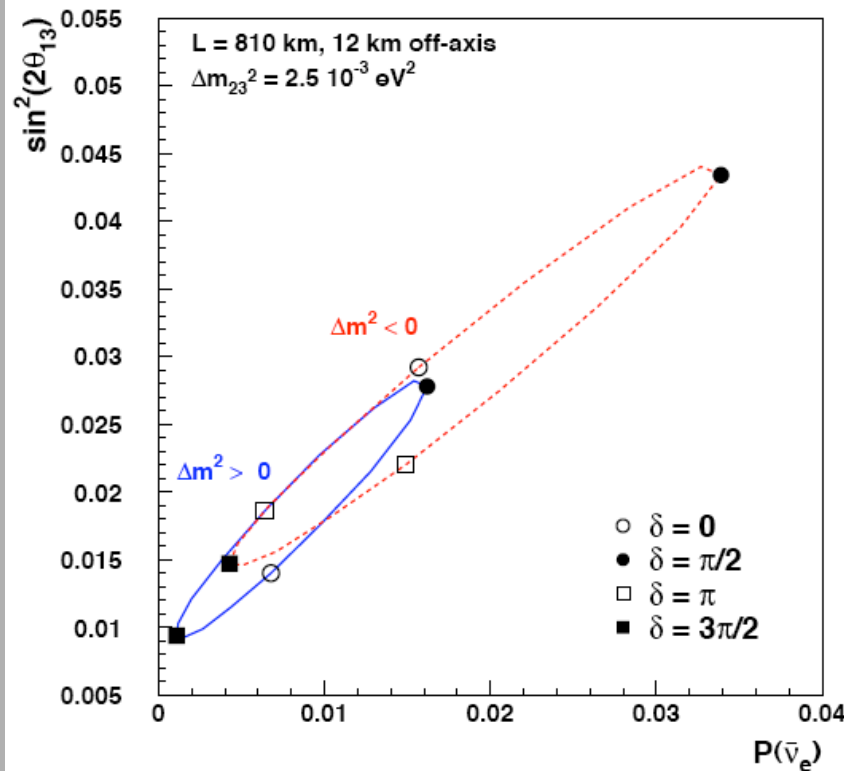
Parameters Consistent with a 2% $\nu_\mu \rightarrow \nu_e$ Oscillation



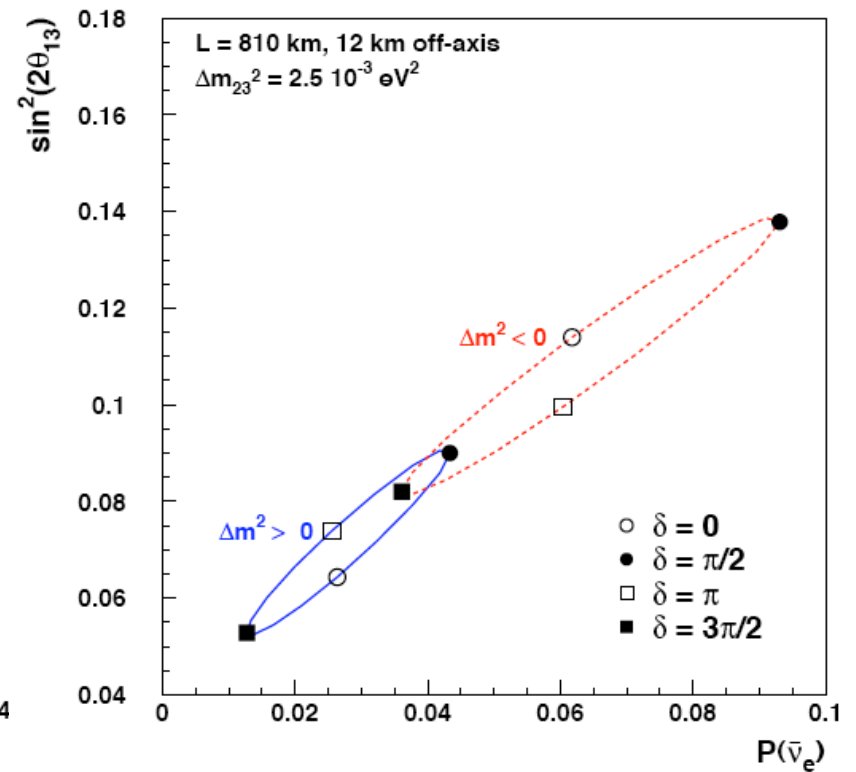


Parameters Consistent with Other Oscillation Probabilities

$\sin^2(2\theta_{13})$ vs. $P(\bar{\nu}_e)$ for $P(\nu_e) = 0.01$

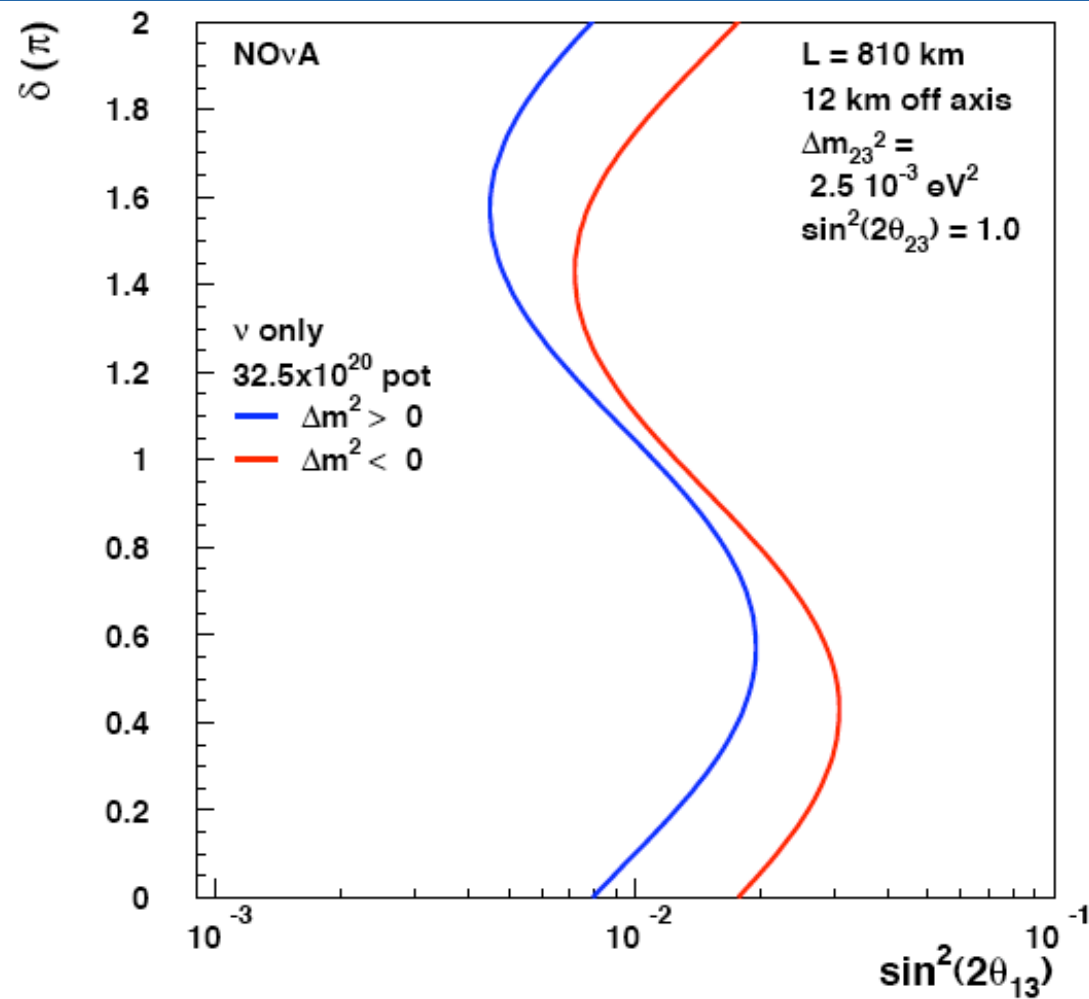


$\sin^2(2\theta_{13})$ vs. $P(\bar{\nu}_e)$ for $P(\nu_e) = 0.04$





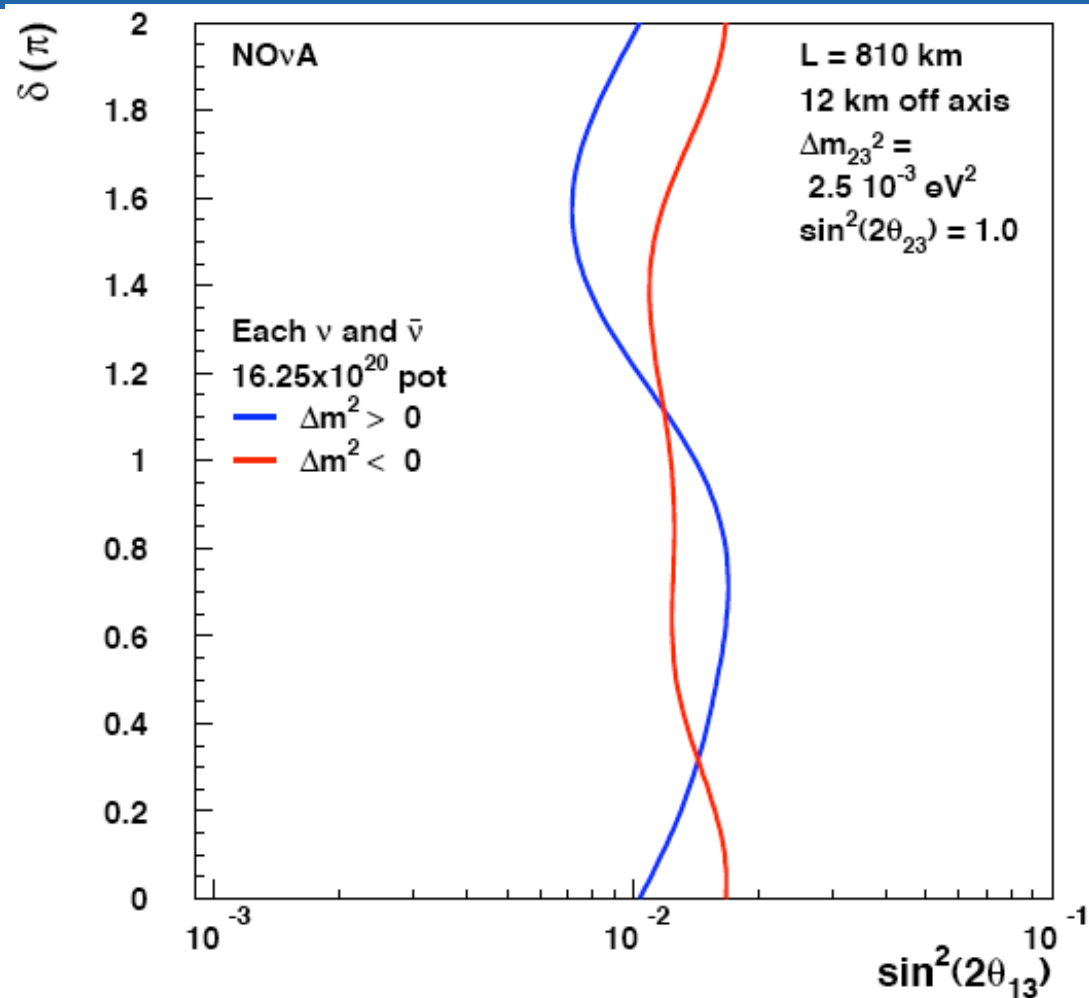
3 σ Sensitivity to $\theta_{13} \neq 0$



**5 year
 ν only
run**



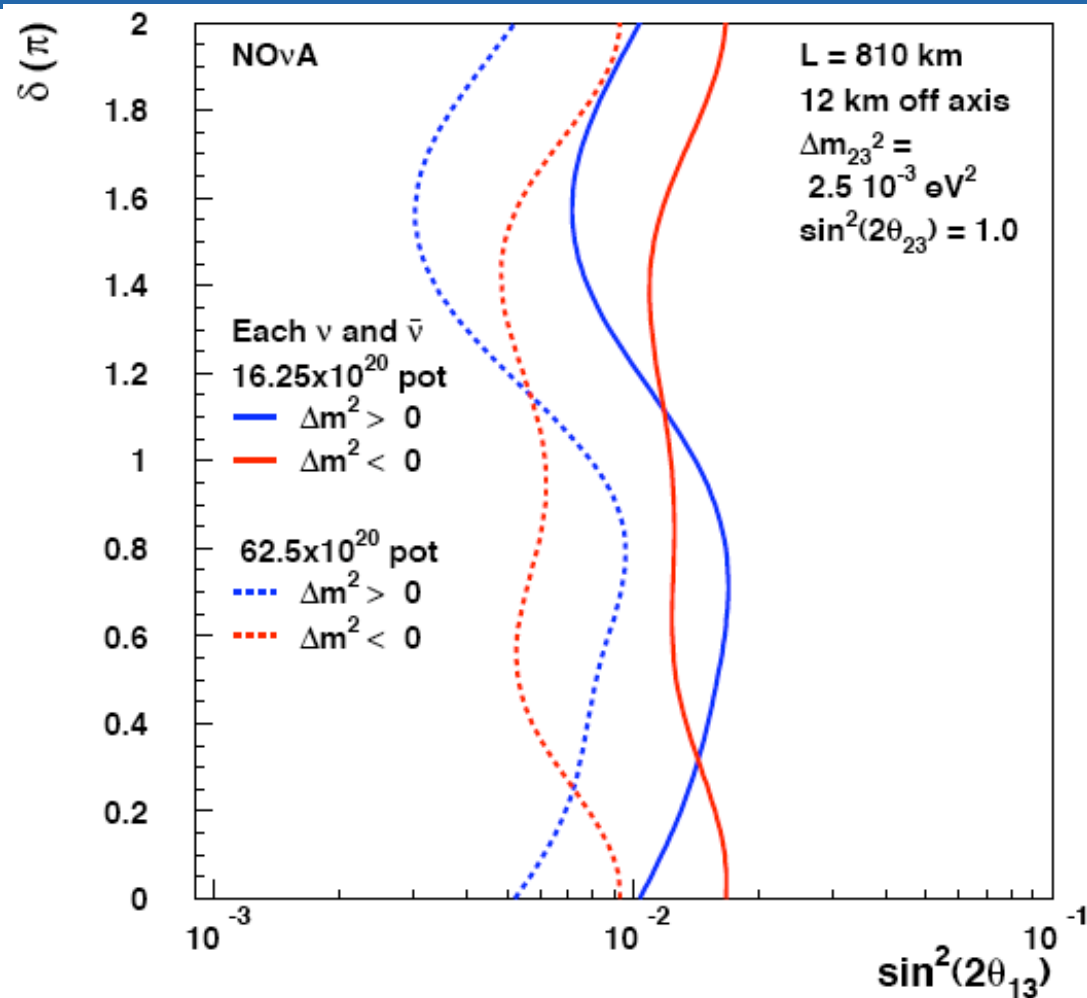
3 σ Sensitivity to $\theta_{13} \neq 0$



**2.5 yr each
 ν and $\bar{\nu}$ run**



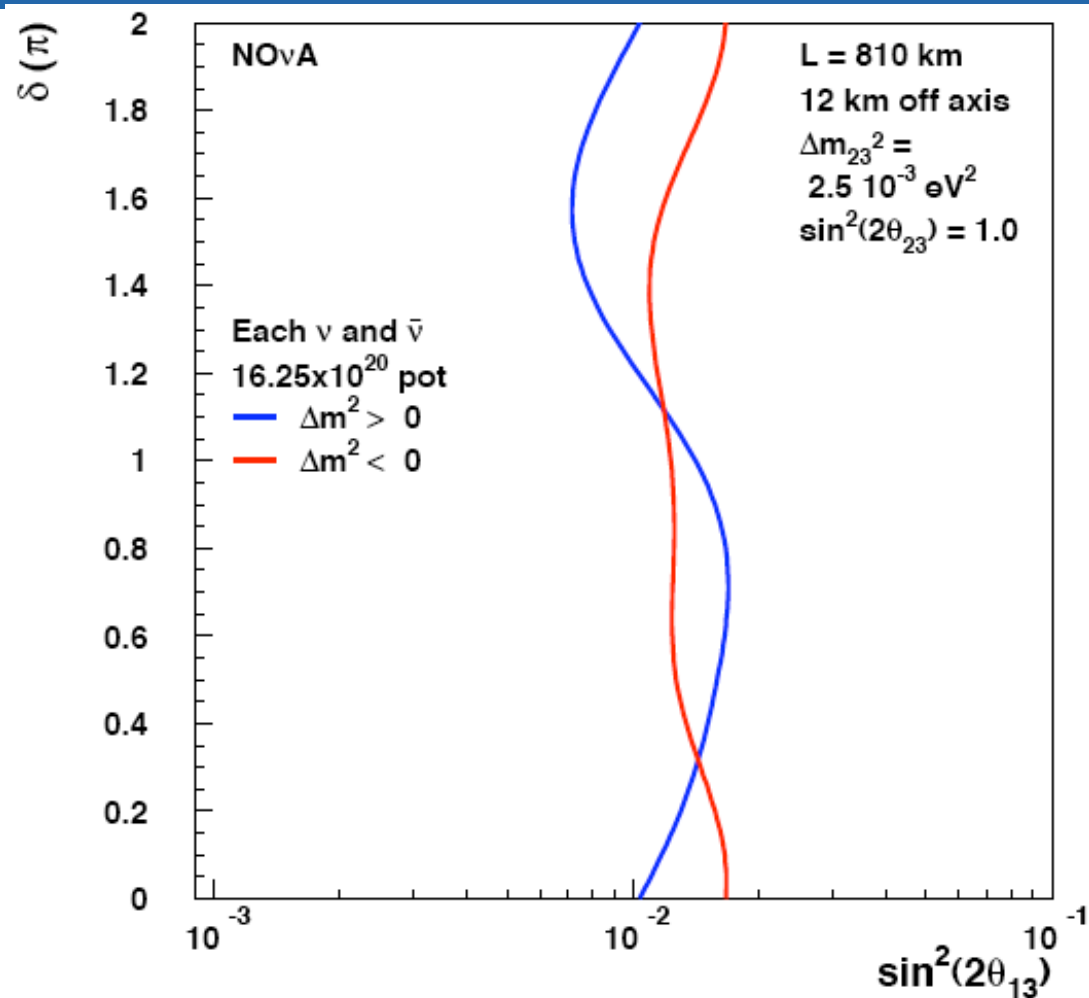
3 σ Sensitivity to $\theta_{13} \neq 0$ Comparison with Proton Driver



2.5 yr each
 ν and $\bar{\nu}$ run



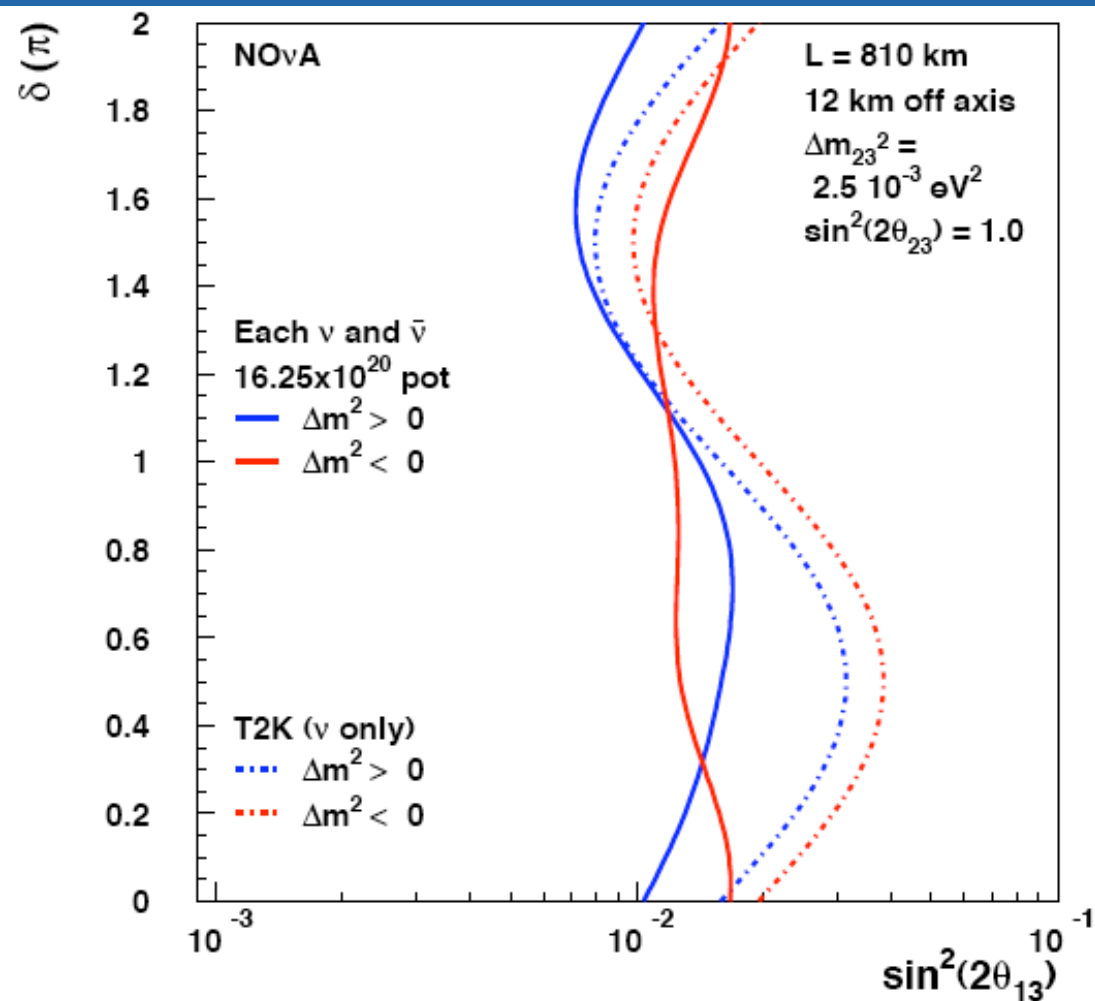
3 σ Sensitivity to $\theta_{13} \neq 0$



2.5 yr each
 ν and $\bar{\nu}$ run



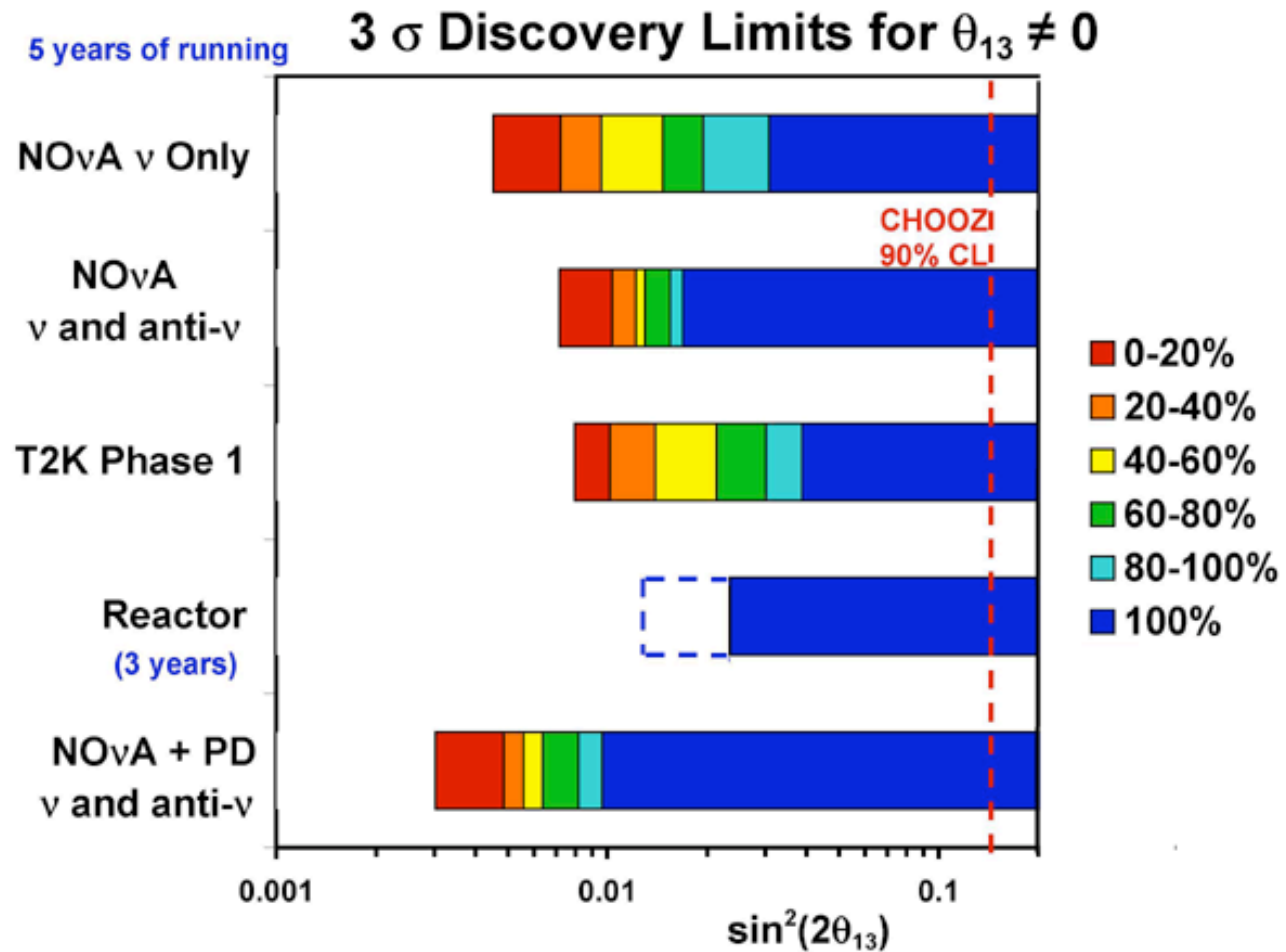
3 σ Sensitivity to $\theta_{13} \neq 0$



2.5 yr each
 ν and $\bar{\nu}$ run



3 σ Sensitivity to $\theta_{13} \neq 0$





Importance of the Mass Ordering

- **Window on very high energy scales: grand unified theories favor the normal mass ordering, but other approaches favor the inverted ordering.**
- **If we establish the inverted ordering, then the next generation of neutrinoless double beta decay experiment can decide whether the neutrino is its own antiparticle. However, if the normal ordering is established, a negative result from these experiments will be inconclusive.**
- **To measure CP violation, we need to resolve the mass ordering, since it contributes an apparent CP violation that we must correct for.**



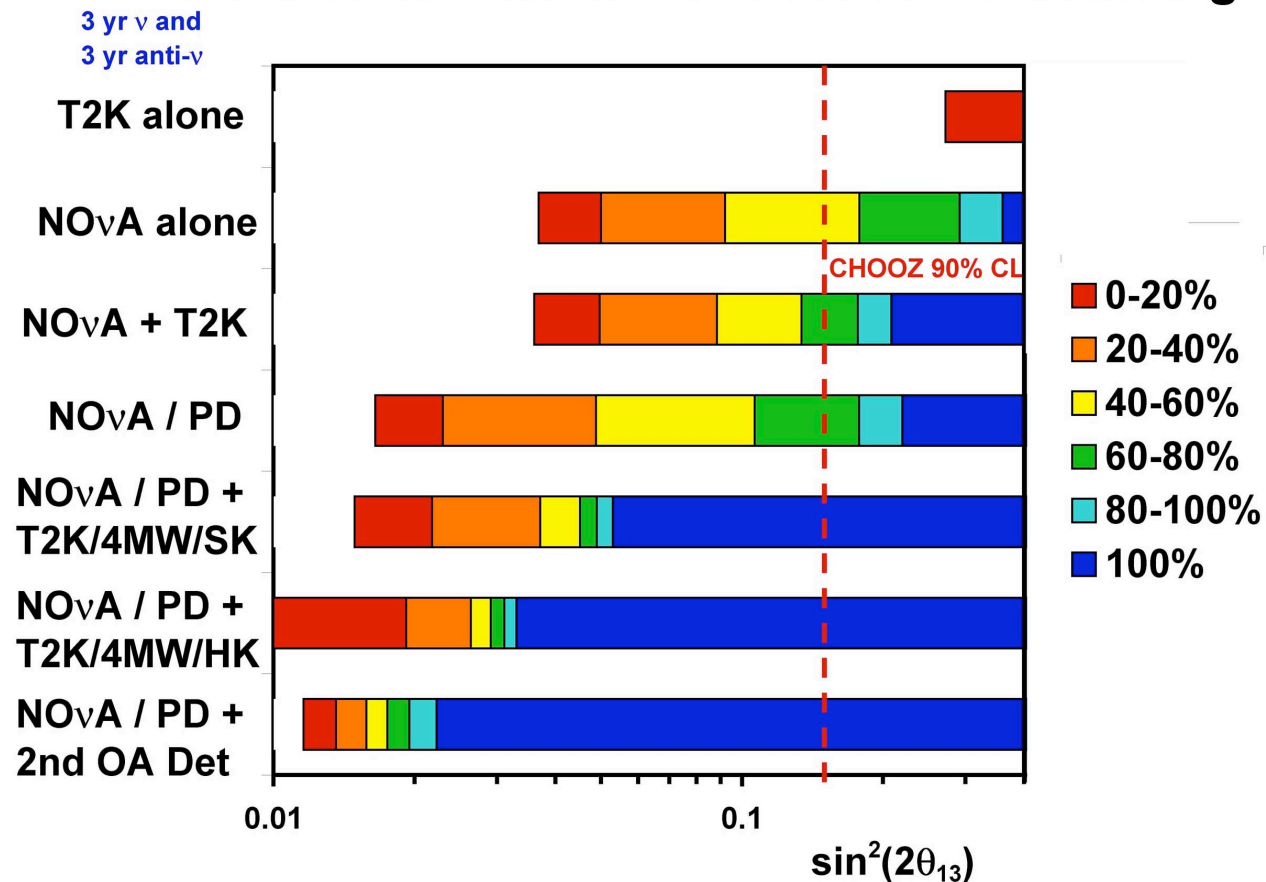
Role of NOvA in Resolving the Mass Ordering

- The mass ordering can be resolved only by matter effects in the earth over long baselines.
- NOvA is the only proposed experiment with a sufficiently long baseline to resolve the mass ordering.
- The siting of NOvA is optimized for this measurement.
- NOvA is the first step in a step-by-step program that can resolve the mass ordering in the region accessible to conventional neutrino beams.



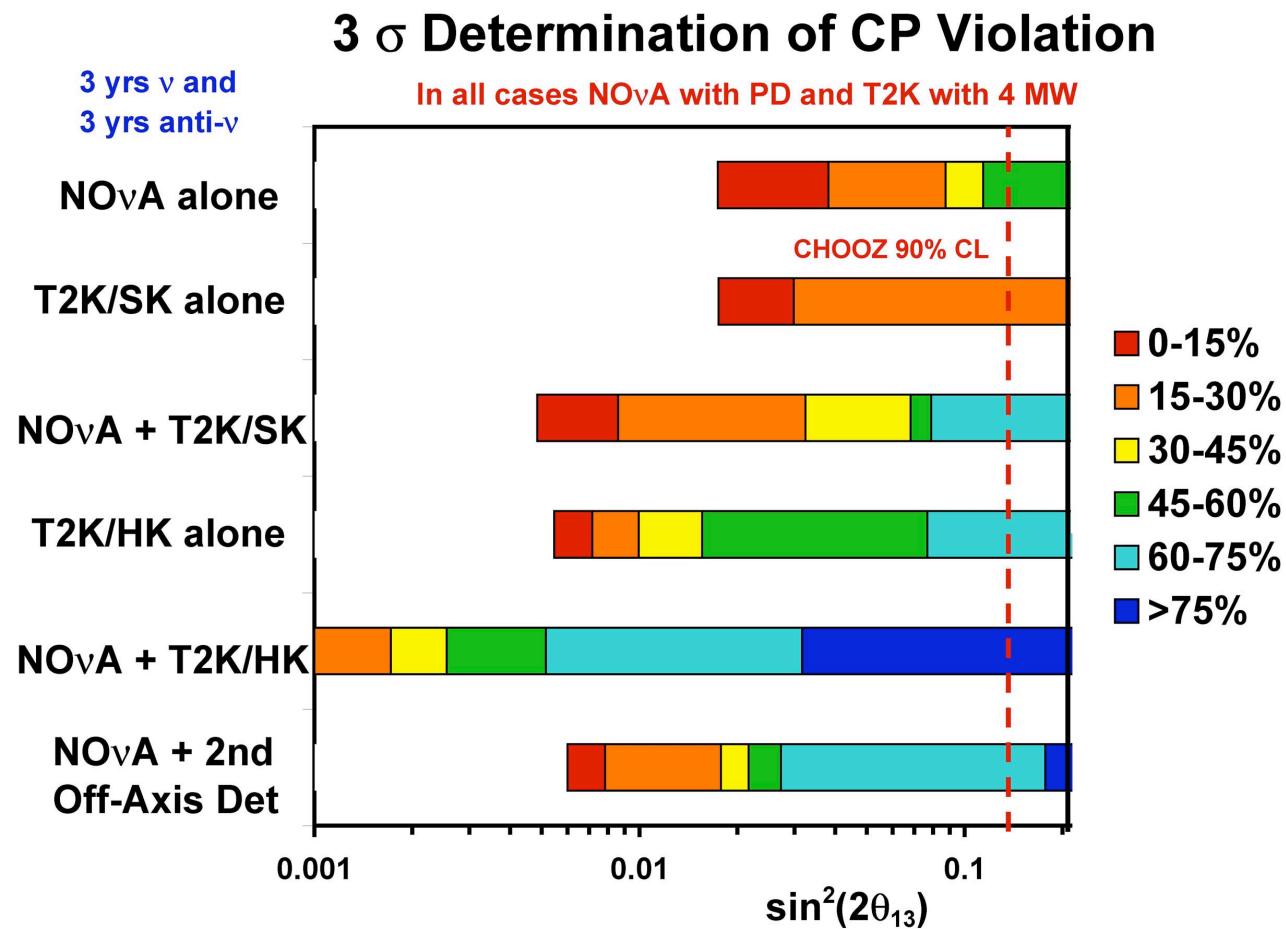
95% CL Resolution of the Mass Ordering

95% CL Determination of the Mass Ordering



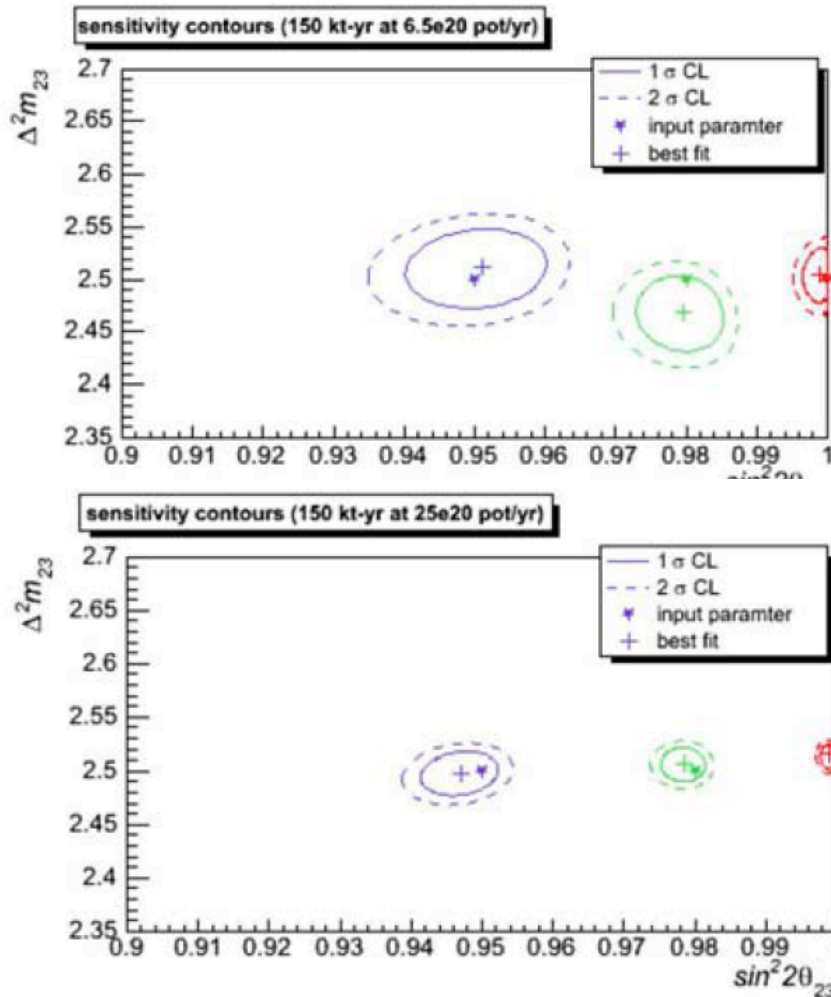


3 σ Determination of CP Violation





Measurement of Δm_{32}^2 and $\sin^2(2\theta_{23})$

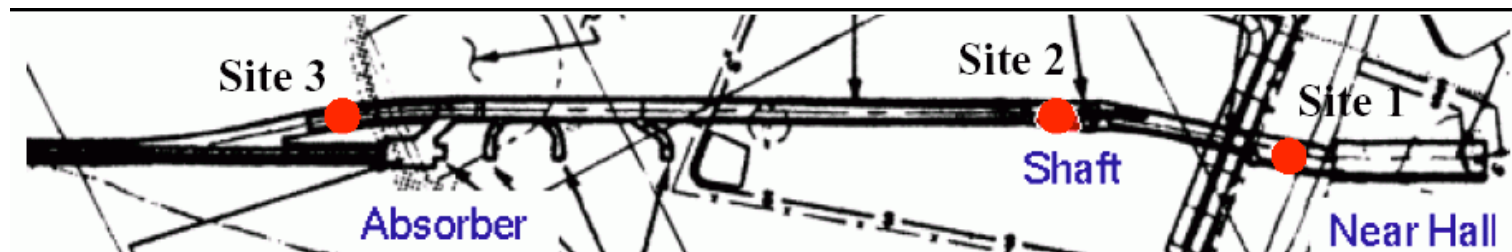
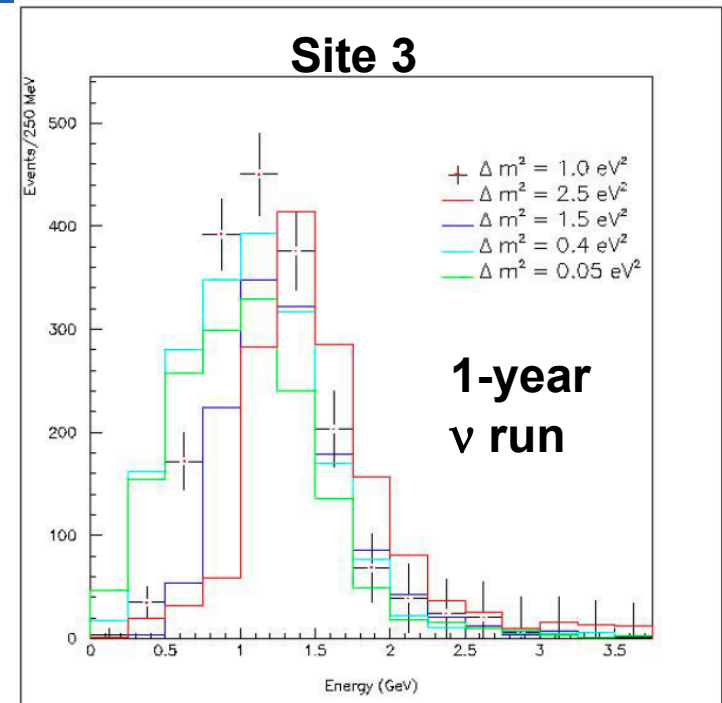
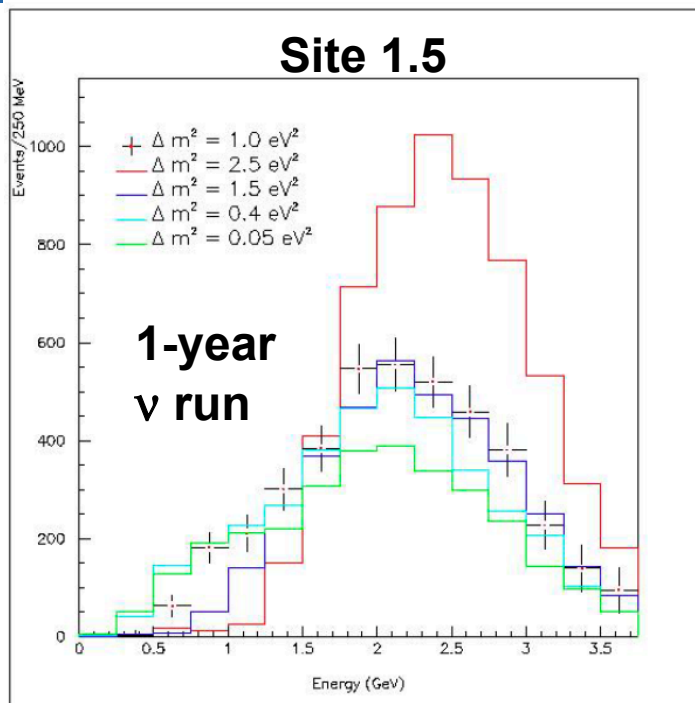


5-year ν run

5-year ν run
with Proton Driver

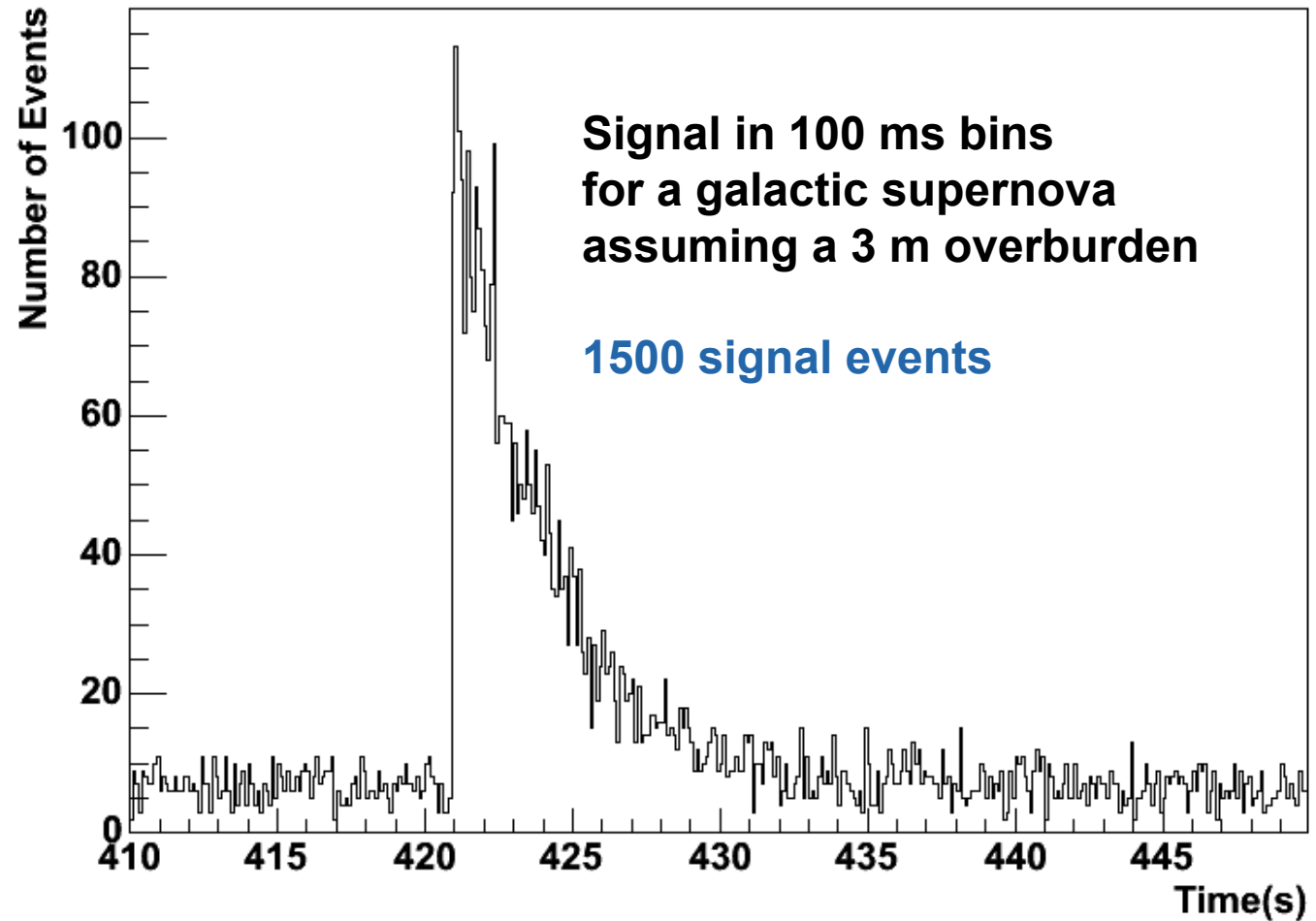


Study MiniBooNE Signal





Sensitivity to a Galactic Supernova





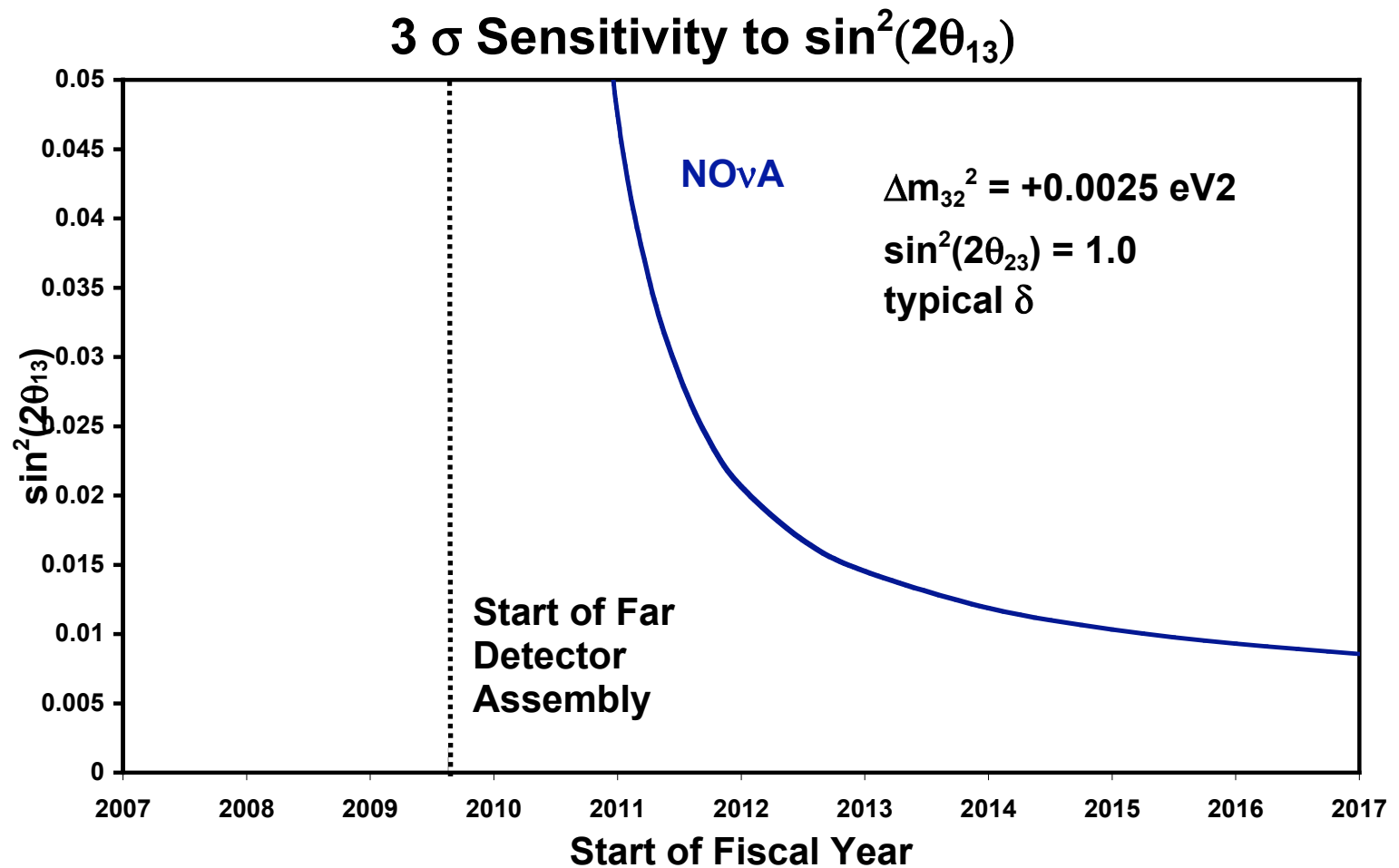
Schedule

(10 of 29 Milestones)

Project start	Oct 2006
R&D prototype Near Detector complete	Mar 2007
Start Far Detector Building construction	Jul 2007
Start receiving packaged APDs	Oct 2007
Start extrusion module factories	Oct 2007
Start construction of Near Detector	Dec 2007
Start operation of Near Detector	Jul 2008
Start Far Detector assembly	May 2009
First kiloton operational	Oct 2009
Full 30 kilotons operational	Jul 2011

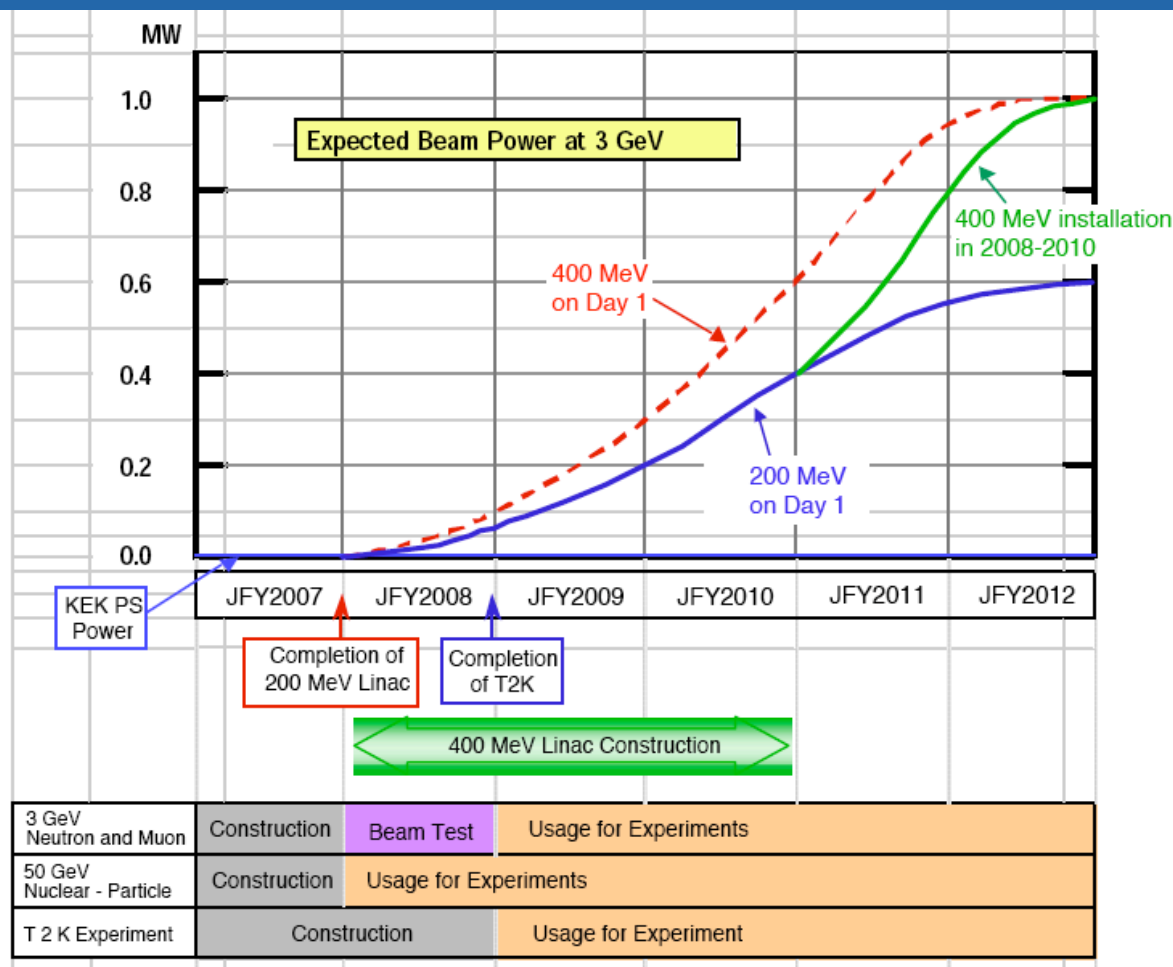


Sensitivity vs. Time





Assumed T2K Beam Power vs. Time



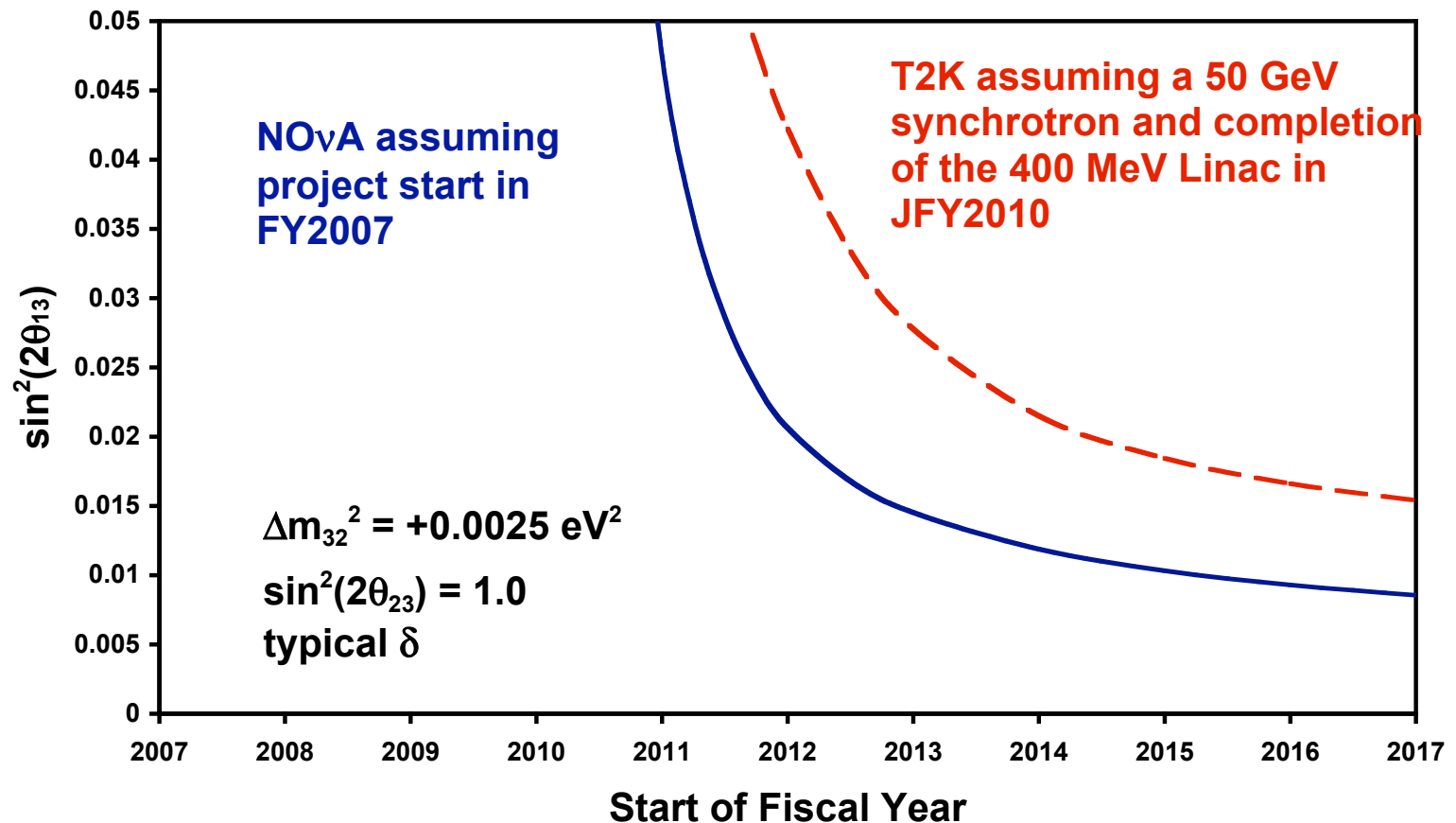
From S. Nagamiya,
Feb 2005



Sensitivity vs. Time

Comparison to T2K

3σ Sensitivity to $\sin^2(2\theta_{13})$





Conclusion

- **NOvA provides a flexible approach to studying all of the parameters of neutrino oscillations**
 - A long baseline approach is crucial in the context of the world program.
 - NOvA is the first stage of a flexible program where each stage can be planned according to what has been learned in previous stages.
 - The NOvA physics reach is greater than other experiments being contemplated for the next few years.
 - The full range of the NOvA/NuMI program is comparable to that of other conventional approaches.
 - NOvA is the size project that can be started now.